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TITLE OF INVENTION

Speaker Apparatus

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APPLICANT(S) FOR DO/EO/US

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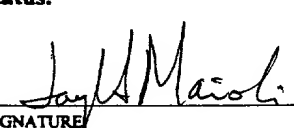
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☐ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:
 - 1.) Formal Drawings
 - 2.) International Search Report
 - 3.) Signed Declaration

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U.S. APPLICATION NO. 09/443044		INTERNATIONAL APPLICATION NO. PCT/JP99/01750		ATTORNEY'S DOCKET NUMBER 7246/01750	
17. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO \$ 970.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) \$ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) \$ ENTER APPROPRIATE BASIC FEE AMOUNT =				CALCULATIONS PTO USE ONLY	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).					
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	4 - 20 =		X	\$	
Independent claims	2 - 3 =		X	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$	\$	
TOTAL OF ABOVE CALCULATIONS =				\$	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				\$	
SUBTOTAL =				\$	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				+	\$ 40.00
TOTAL FEES ENCLOSED =				\$	1,010.00
				Amount to be:	\$
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a. <input checked="" type="checkbox"/> A check in the amount of \$ <u>1,010.00</u> to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>03-3125</u> . A duplicate copy of this sheet is enclosed.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO: Jay H. Maioli Cooper and Dunham LLP 1185 Avenue of the Americas New York, NY 10036					
				 SIGNATURE Jay H. Maioli	
				NAME 27,213	
				REGISTRATION NUMBER	

5/pats

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VERIFICATION OF A TRANSLATION

I, the below named translator, hereby declare that:
My name and post office address are as stated
below;

That I am knowledgeable in the English language and
in the language in which the below identified
international application was filed, and that I believe
the English translation of the international application
No. PCT/JP99/01750 is a true and complete translation of
the above identified international application as filed.

I hereby declare that all statements made herein
of my own knowledge are true and that all statements made
on information and belief are believed to be true;
and further that these statements were made with the
knowledge that willful false statements and the like so
made are punishable by fine or imprisonment, or both,
under Section 1001 of Title 18 of the United States Code
and that such willful false statements may jeopardize
the validity of the application or any patent issued
thereon.

Date November 25, 1999

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DESCRIPTION

Speaker Apparatus

Technical Field

5 The present invention relates to a speaker apparatus for use with various audio units and video units.

Related Art

10 A conventional speaker apparatus is structured as shown in Fig. 6. Such a speaker apparatus is referred to as dynamic speaker. The speaker apparatus has a magnetic circuit that comprises a doughnut shaped magnet 1, a first magnetic yoke 2, a second magnetic yoke 3, and a gap 4. The first and second magnetic yokes 2 and 3 are composed of a magnetic material such as steel. The first magnetic yoke 2 is composed of a cylindrical pole piece 2a and a disc shaped flange portion 2b. The disc shaped flange portion 2b is perpendicular to the center pole portion 2a. The second magnetic yoke 3 is referred to as plate. The second magnetic yoke 3 is doughnut shaped in such a manner that the inner diameter of the second magnetic yoke 3 is larger than the outer peripheral diameter of the pole piece 2a by the gap 4.

25 The magnet 1 is adhered to the front surface of the flange portion 2b of the first magnetic yoke 2 and the plate 3 in such a manner that the pole piece 2a is inserted into an inner peripheral hollow portion of

the magnetic 1 and an inner peripheral hollow portion of the plate 3.

A voice coil 6 is disposed around a voice coil bobbin 5 and in the gap 4 formed between the plate 3 and the pole piece 2a. The voice coil bobbin 5 is composed of a non-conductor. An acoustic vibrating plate 7 is adhered to the voice coil bobbin 5. The acoustic vibrating plate 7 is for example cone paper. An edge portion of the acoustic vibrating plate 7 is fixedly to a speaker frame 8. A signal input line (lead line) 9 is connected to the voice coil 6.

In the speaker apparatus shown in Fig. 6, when a current I corresponding to an acoustic signal flows in the voice coil 6, an interaction of the current I and a magnetic flux B of the magnetic gap 4 causes driving force F that vibrates the acoustic vibrating plate 7 to take place. The driving force F can be expressed by formula (1).

$$F = B \times I \times D \quad \dots (1)$$

where D is the length of the voice coil 6 in the magnetic field.

Since the dynamic speaker apparatus has a signal input line in the vibrating system, the signal input line adversely affects the vibrating balance of the acoustic vibrating system. In addition, the signal current that flows in the voice coil 6 causes it to heat. Thus, it is necessary to consider the damage of

the bobbin due to the heat generated by the voice coil
6. Consequently, the amount of the signal current that
flows in the voice coil 6 is restricted.

In addition, an electromagnetic induction
5 type speaker apparatus is also known. In the
electromagnetic induction type speaker apparatus, an
exciting primary coil is disposed around a pole piece.
A secondary coil composed of a conductive one-turn ring
is disposed in a gap of a magnetic circuit. When a
10 signal current flows in the primary coil, a current is
induced in the secondary coil. When the induced
current cuts a magnetic flux in the gap, driving force
that drives an acoustic vibrating plate connected to
the secondary coil is generated.

In the electromagnetic induction type speaker
15 apparatus, since the exciting primary coil to which the
signal current is supplied is disposed around the pole
piece that has high heat conductivity, the primary coil
can easily radiate heat. Thus, a relatively large
20 amount of signal current can be supplied to the primary
coil. In addition, since the vibrating system does not
have a signal input line, the vibrating balance of the
acoustic vibrating system is good.

However, recently, as recording technologies
25 and recording mediums have advanced, it has become
clear that an acoustic component that exceeds the
audible frequency band of ears of humans (20 kHz or

higher) affects a reproduction acoustic output corresponding to auditory sense. Thus, a microphone with a wide frequency band of 100 kHz or higher as a sound pickup characteristic is known.

5 Thus, a speaker apparatus that properly reproduces an acoustic component that exceeds the audible frequency band (20 kHz or higher) has been desired.

10 In the case of the conventional typical speaker apparatus as shown in Fig. 6, since the voice coil 6 has a DC resistance R_1 and an inductance component L_1 , when the frequency exceeds the resonance frequency f_0 , the input impedance Z_{in} of the speaker apparatus can be expressed by formula (2).

15
$$Z_{in} = R_1 + j \cdot 2 \cdot \pi \cdot L_1 \quad \dots (2)$$

From formula (2), it is clear that the input impedance Z_{in} is proportional to the frequency f . Thus, as the frequency f becomes high, the current I that flows in the voice coil 6 decreases. In the speaker apparatus shown in Fig. 6, the driving force F becomes weak. Thus, the speaker apparatus shown in Fig. 6 is not suitable for reproducing an acoustic component that exceeds the audible frequency band of 20 kHz or higher.

20 The electromagnetic induction type speaker apparatus has the above-described features. However, the amount of the induction current that flows in the secondary coil composed of a one-turn conductive ring

varies corresponding to the constants of the primary coil and the secondary coil. Depending on selected values of the constants of the primary coil and the secondary coil, even if the amount of the signal current that flows in the primary voice coil is large, a desired amount of current as an induced current does not flow. Thus, the efficiency of the electromagnetic inductive type speaker apparatus becomes low.

Disclosure of the Invention

The present invention is made from the above-described point of view. An object of the present invention is to allow an acoustic component of 20 kHz or higher to be properly reproduced.

Another object of the present invention is to allow a current to be effectively induced in a secondary coil of an electromagnetic induction type speaker apparatus.

A speaker apparatus of claim 1 comprises a primary coil disposed in the vicinity of a gap of a magnetic circuit and to which a current corresponding to an input audio signal is supplied, a secondary coil, disposed in the gap, for inducing a current corresponding to a current that flows in the primary coil, and a vibrating plate vibrated by the secondary coil with an interaction of the current induced by the secondary coil and a magnetic flux in the gap, wherein the following formula is satisfied

$$N \times (R_1 \times R_2)^{1/2} / (2 \pi \times L_1 \times (1 - k^2)^{1/2}) \geq 20000 \quad \dots (3)$$

where R_1 is the DC resistance of the primary coil, L_1 is the inductance of the primary coil, N is the number of turns of the primary coil, R_2 is the DC resistance of the secondary coil, and k is the coupling coefficient of the primary coil and the secondary coil.

A speaker apparatus of claim 2 is the speaker apparatus of claim 1, wherein the individual constants R_1 , L_1 , N , R_2 , and k satisfy formula (4) at a frequency f in a desired reproduction frequency band

$$2 \pi \times f \times L_1 \times (N^2 \times R_2 + R_1) / (N^2 \times X^{1/2}) \geq 0.3$$

$$X = (2 \pi \times f)^2 \times (L_1 \times R_2 + L_1 \times R_1 / N^2)^2 + \{-R_1 \times R_2 + (2 \pi \times f)^2 \times L_1 \times (1 - k^2) / N^2\}^2 \quad \dots (4)$$

A speaker apparatus of claim 3 comprises a primary coil disposed in the vicinity of a gap of a magnetic circuit and to which a current corresponding to an input audio signal is supplied, a secondary coil, disposed in the gap, for inducing a current corresponding to a current that flows in the primary coil, and a vibrating plate vibrated by the secondary coil with an interaction of the current induced by the secondary coil and a magnetic flux in the gap, wherein the following relation is satisfied

$$L_1 / L_2 = R_1 / R_2$$

where R_1 is the DC resistance of the primary

coil, L_1 is the inductance of the primary coil, R_2 is the DC resistance of the secondary coil, and L_2 is the inductance of the secondary coil.

According to claim 1 of the present invention, as a driving method for an acoustic vibrating plate, an electromagnetic inducting method is used. The values of the individual constants are determined in such a manner that formula (3) is satisfied. Thus, since the inductance component of the input impedance becomes low and thereby allows a predetermined amount of a current to flow, predetermined driving force can be obtained in a high frequency band of 20 kHz or higher.

According to claim 2 of the present invention, since the values of the individual constants are determined in such a manner that formula (4) is satisfied, the amount of an induced current at a desired reproduction frequency f can be limited to -10 dB or less of the maximum current. Thus, desired driving force can be obtained in the high frequency band of 20 kHz or higher.

According to claim 3 of the present invention, since the constants of the primary coil and the secondary coil are selected, the induced current that flows in the secondary coil becomes maximum. Thus, an electromagnetic induction type speaker with high efficiency can be accomplished.

Brief Description of Drawings

Fig. 1 is a sectional view showing an example of the structure of a speaker apparatus according to a first mode of the present invention;

5 Fig. 2 is a schematic diagram showing an electric equivalent circuit of an electromagnetic induction portion of the speaker apparatus according to the first mode of the present invention;

10 Fig. 3 is a graph showing a measurement example of input impedance of the speaker apparatus according to the first mode of the present invention;

15 Fig. 4 is a graph showing a frequency characteristic of an induced current of the speaker apparatus according to the first mode of the present invention;

20 Fig. 5 is a graph showing a frequency characteristic of an induced current of a speaker apparatus according to a second mode of the present invention; and

25 Fig. 6 is a sectional view showing an example of the structure of a conventional dynamic speaker apparatus.

Best Modes for Carrying out the Invention

25 Next, with reference to the accompanying drawings, a speaker apparatus according to a first mode of the present invention will be described. According to the present invention, an acoustic vibrating plate

is driven by the electromagnetic inducing method.

Fig. 1 shows the structure of an electromagnetic induction type speaker apparatus according to the first mode of the present invention.

5 In the speaker apparatus shown in Fig. 1, the structure of a magnetic circuit is the same as that of the speaker apparatus shown in Fig. 6. In other words, the magnetic circuit of the speaker apparatus shown in Fig. 1 is composed of a first yoke 12, a doughnut shaped plate 13, a doughnut shaped magnet 11, and a gap 14. The first yoke 12 has a cylindrical pole piece 12a and a disc shaped flange portion 12b. The doughnut shaped plate 13 composes a second yoke. The doughnut shaped magnet 11 is disposed between the flange portion 12b of the first yoke 12 and the plate 13. The gap 14 is formed between the plate 13 and the pole piece 12a.

10 A driving coil as an exciting primary coil is disposed at an outer peripheral portion of the pole piece 12a facing the gap 14 or/and at an inner peripheral portion of the plate 13. According to the first mode of the present invention, an exciting primary coil 15 is disposed at an outer peripheral portion of the pole piece 12a. To disposed the primary coil 15, a small diameter portion with the length of the windings of the primary coil 15 may be formed in the vicinity of the vertex portion of the pole piece 12a.

A signal input line (lead line) 16 is connected from the primary coil 15 to the rear side of the flange portion 12b through a through-hole 17 formed in the flange portion 12b of the first magnetic yoke 12.

According to the first mode of the present invention, a secondary coil 18 is inserted in the gap 14. The secondary coil 18 is composed of a short coil that electromagnetically couples with the primary coil 15. In this example, the secondary coil 18 is a one-turn short coil composed of a non-magnetic and conductive material such as a cylindrical ring of aluminum. The conductive one-turn ring composed of aluminum of the secondary coil 18 is adhered to the bobbin 19. The bobbin 19 is composed of a non-magnetic and non-conductive material such as a card board.

The width of the secondary coil 18 (equivalent to the height of the one-turn ring) is longer than the length in the vibrating direction of the gap 14 by the length of the amplitude of the vibration of the secondary coil 18. However, the width of the secondary coil 18 should be as small as possible.

The acoustic vibrating plate 20 (for example, a cone paper) is disposed to the bobbin 19. The acoustic vibrating plate 20 is disposed to a speaker frame 21 through a flexible edge (not shown).

In the electromagnetic induction type speaker apparatus, when a signal current is supplied to the exciting primary coil 15, an induced current flows in the one-turn ring as the secondary coil 18 disposed opposite to the primary coil. The induced current I that flows in the secondary coil 18 and the magnetic flux density B in the gap 14 cause driving force F that drives the secondary coil 18 in the direction of the height of the ring to take place. Thus, the acoustic vibrating plate 20 is vibrated corresponding to the signal current.

In this case, the driving force F can be expressed by formula (5)

$$F = B \times I \times L \quad \dots (5)$$

where L is the length of the one-turn ring as the secondary coil 18 (namely, the circumference of the ring).

According to the first mode of the present invention, the individual constants of the primary coil 15 and the secondary coil 18 are selected in such a manner that following formula (6) is satisfied.

$$N \times (R1 \times R2)^{1/2} / (2 \pi \times L1 \times (1 - k2)^{1/2}) \geq 20000 \quad \dots (6)$$

where R1 is the DC resistance of the primary coil 15; L1 is the inductance of the primary coil 15; N is the number of turns of the primary coil 15; R2 is the DC

resistance of the secondary coil 18; k is the coupling coefficient of the primary coil 15 and the secondary coil 18.

In addition, the constants R1, L1, R2, and k are selected in such a manner that formula (7) is satisfied.

$$2 \pi \times f \times L_{12} \times (N_2 \times R_2 + R_1) / (N_2 \times X^{1/2}) \geq 0.3$$

$$X = (2 \pi \times f)^2 \times (L_1 \times R_2 + L_1 \times R_1 / N_2)^2 + \{-R_1 \times R_2 + (2 \pi \times f)^2 \times L_{12} \times (1 - k^2) / N_2\}^2 \dots (7)$$

Since the individual constants R1, L1, R2, and k are selected in such a manner, in a high frequency band of 20 kHz or higher, a constant current can be supplied. Thus, desired driving force can be obtained. In particular, when the individual constants R1, L1, R2, and k are set in such a manner that formula (7) is satisfied, the decrease of the induced current at a desired high frequency can be suppressed within 10 dB against the maximum induced current as will be described next.

The electric equivalent circuit of the electromagnetic induction portion of the electromagnetic induction type speaker apparatus is shown in Fig. 2. In Fig. 2, R1 and L1 are the DC resistance and the inductance of the exciting primary coil 15, respectively; R2 and L2 are the DC resistance and the inductance of the secondary coil 18,

respectively; M is the mutual inductance; and Z_{in} is the input impedance of the speaker apparatus.

According to the equivalent circuit shown in Fig. 2, the input impedance Z_{in} of the speaker apparatus can be expressed by formula (8).

$$Z_{in} = (R_1 + A_2 + R_2) + j\omega (L_1 - A_2 \times L_2). \quad (8)$$

$$A_2 = \omega^2 \times M^2 / (\omega^2 \times L_2^2 + R_2^2)$$

$$M = k^2 \times L_1 \times L_2$$

where ω is the angular frequency.

When the frequency f is high, the following relation is satisfied.

$$A_2 = M^2 / L_2^2 = k^2 \times L_1 / L_2$$

Thus, formula (8) can be expressed by formula (9).

$$Z_{in} = (R_1 + k^2 \times R_2 \times L_1 / L_2) + j\omega L_1 (1 - k^2) \quad \dots (9)$$

In addition, when only the exciting primary coil 15 is used, the input impedance Z_{in} can be expressed by formula (10).

$$Z_{in} = R_1 + j\omega L_1 \quad \dots (10)$$

When formula (9) and formula (10) are compared, it is clear that when the secondary coil 18 is used in a high frequency band, the inductance component becomes small due to the coupling coefficient k . In particular, when the coupling coefficient k is 1, the inductance component in the high frequency band becomes very small. Thus, it is clear that the input

impedance becomes constant against the frequency.

Since the inductance component of the input impedance Z_{in} becomes small without need to decrease the inductance component of the exciting primary coil 15, a constant current flows in the secondary coil in a high frequency band of 20 kHz or higher. Thus, constant driving force can be obtained.

When the electromagnetic induction type speaker apparatus is driven at a constant voltage, the frequency characteristic of the induced current that flows in the one-turn ring as the secondary coil 18 can be expressed by formula (11).

$$I_2 / V_1 = \omega \cdot k (L_1 \times L_2)^{1/2} / Y^{1/2}$$
$$Y = \omega^2 \times (L_1 \times R_2 + L_2 \times R_1)^2 + \{-R_1 \times R_2 + \omega^2 \times L_1 \times L_2 \times (1 - k^2)\}^2 \quad \dots (11)$$

From formula (11), the frequency f_0 at which the induced current I_2 becomes maximum is given by formula (12).

$$f_0 = N \times (R_1 \times R_2)^{1/2} / \{2\pi \times L_1 \times (1 - k^2)^{1/2}\} \quad \dots (12)$$

When formula (6) is satisfied, the relation $f_0 \geq 20000$ is required. Thus, in a high frequency band of 20 kHz or higher, the induced current becomes maximum.

To satisfy formula (7), the decrease of the induced current at a desired frequency f in a high frequency band of 20 kHz or higher can be suppressed

within 10 dB against the maximum current.

Next, a second mode of the present invention will be described. The structure of an electromagnetic induction type speaker apparatus according to the second mode is similar to that according to the first mode shown in Fig. 1. In the second mode, the individual constants are selected in such a manner that formula (13) is satisfied

$$L1 / L2 = R1 / R2 \quad \dots (13)$$

where R1 is the DC resistance of the primary coil 15; L1 is the inductance of the primary coil 15; R2 is the DC resistance of the secondary coil 18; and L2 is the inductance of the secondary coil 18.

When the coupling coefficient k of the primary coil 15 and the secondary coil 18 is equal to 1, formula (13) can be expressed by formula (14).

$$N2 = R1 / R2$$

$$L1 / L2 = N2 \quad \dots (14)$$

Since the individual constants L1, L2, R1, and R2 are selected in such a manner, the induced current of the secondary coil 18 as the driving force of the acoustic vibrating plate becomes maximum. Thus, an electromagnetic induction type speaker apparatus with high efficiency can be accomplished. The square of the number of turns of the primary coil is proportional to the ratio of the DC resistance R1 of the primary coil and the DC resistance R2 of the

secondary coil as will be described next.

The electric equivalent circuit of an electromagnetic induction portion of the electromagnetic induction type speaker apparatus according to the second mode is the same as that according to the first mode shown in Fig. 2. For simplicity, in the second mode, the description of similar portions to those of the electromagnetic induction portion of the first mode is omitted.

When the electromagnetic induction type speaker apparatus according to the second mode is driven at a constant voltage, the frequency characteristic of an induced current that flows in a one-turn ring as a secondary coil 18 can be expressed by formula (15).

$$I_2 / V_1 = \omega \cdot k (L_1 \times L_2)^{1/2} / Y^{1/2}$$
$$Y = \omega^2 \times (L_1 \times R_2 + L_2 \times R_1)^2 + \{-R_1 \times R_2 + \omega^2 \times L_1 \times L_2 \times (1 - k^2)\}^2 \quad \dots (15)$$

where V_1 is the driving voltage; I_2 is the induced current of the secondary coil 18.

Because of formula (15), the maximum value I_2 / V_1 (max) of the induced current I_2 can be expressed by formula (16).

$$I_2 / V_1 \text{ (max)} = k \times (L_1 \times L_2)^{1/2} / (L_1 \times R_2 + L_2 \times R_1) \quad \dots (16)$$

When formula (14) is satisfied, the right side of formula (16) becomes maximal. In other words,

the induced current I2 becomes maximum.

As expressed by formula (13), when the ratio of the inductance L1 of the exciting primary coil 15 and the inductance L2 of the secondary one-turn conductive ring 18 is equal to the ratio of the DC resistance of the coil 15 and the DC resistance of the coil 18, it is clear that the induced current I2 of the secondary coil 18 becomes maximum.

When the coupling coefficient k is equal to 1, as expressed by formula (14), it is clear that when the square of the number N of turns of the exciting primary coil 15 is equal to the ratio of the DC resistance R1 of the exciting primary coil 15 and the DC resistance R2 of the secondary coil 18, the induced current I2 becomes maximum.

[First Embodiment]

Next, an exciting primary coil 15 and a secondary coil 18 of a speaker apparatus according to a first embodiment based on the first mode of the present invention will be described.

In the first embodiment, the sizes and characteristics of the exciting primary coil 15 and the one-turn ring as the secondary coil 18 are as follows:

Exciting primary coil 15:

Diameter = 13 mm; winding width = 2.6 mm;
number of winding layers = 2; total number of turns (N)
= 33; DC resistance (R1) = 3.22 Ω ; inductance (L1) =

34.5 μH

Secondary coil 18 (one-turn ring):

Diameter (inner diameter) = 13.36 mm; width =
3.0 mm; thickness = 0.2 mm; material = aluminum; DC
resistance (R_2) = 0.00207 Ω ; inductance (L_2) = 0.032 μH

In this case, the inductance L_2 is almost
equal to L_1 / N_2 .

Fig. 3 shows a measurement example of the
frequency characteristic of input impedance of the
speaker apparatus according to the first embodiment.
In Fig. 3, "." represents a measurement point of the
frequency characteristic of input impedance in the case
that the secondary coil 18 is not used, whereas "+"
represents a measurement point of the frequency
characteristic of input impedance in the case that the
secondary coil 18 is used.

As is clear from the measurement values, the
inductance component of the input impedance of the
electromagnetic induction type speaker apparatus is
remarkably small. When the above-mentioned values of
the individual constants R_1 , L_1 , N , and R_2 are
substituted into the left side of formula (6) (same as
formula (3)), the left side becomes 22907. Thus,
formula (6) is satisfied. According to the measurement
result, the coupling coefficient k is 0.84.

When the above-mentioned values of the
individual constants R_1 , L_1 , N , R_2 , and k are

substituted into the left side of formula (4), the left side becomes 0.67. Thus, the relation of formula (7) (same as formula (4)) is satisfied.

Fig. 4 shows a calculation example of the frequency characteristic of relative values of induced current using the above-mentioned values of the individual constants R_1 , L_1 , N , and R_2 and formula (12). As described above, in the first embodiment of which the coupling coefficient k is 0.84, the decrease of the induced current at 100 kHz is 3.5 dB against a value at 20 kHz.

As another example, when the coupling coefficient k is 1.0, a constant driving current (induced current) flows in the secondary coil in a frequency band from 20 kHz to 100 kHz. When the coupling coefficient k is 0.74, the decrease of the induced current at 100 kHz is 6 dB against a value at 20 kHz.

When the values of the individual constants R_1 , L_1 , N , R_2 , and k are set in such a manner that formula (6) (same as formula (3)) and formula (7) (same as formula (4)) are satisfied. The decrease of the induced current at up to a desired high frequency of 20 kHz or higher can be suppressed within 10 dB.

[Second Embodiment]

Next, an exciting primary coil 15 and a secondary coil 18 of a speaker apparatus according to a

second embodiment based on the second mode of the present invention will be described.

In the second embodiment, the characteristics of the exciting primary coil 15 and the one-turn ring as the secondary coil 18 are as follows. The frequency characteristic of the driving force is calculated corresponding to the amount of the induced current. In this example, the inductance L2 of the secondary coil 18 that is a one-turn conductive ring is a parameter. The coupling coefficient k is 0.9. The driving voltage V1 is 4 V. The magnetic flux density of the magnetic circuit is 1.5 T. The length of the one-turn conductive ring is 0.042 m.

Exciting primary coil 15:

DC resistance (R1) = 3.22 Ω

Inductance (L1) = 34.5 μ H

Secondary coil 18 (one-turn conductive ring):

DC resistance (R2) = 0.00207 Ω

Inductance (L2) = parameter

Fig. 5 shows the calculation result. Thus, from Fig. 5, it is clear that when the ratio of L1 / L2 satisfies formula (13), the driving force becomes maximum. When the coupling coefficient k is 1, from formula (14), the number of turns N is set to 3.

In the second embodiment, constants are determined by varying the inductance L2 of the secondary coil 18 as a one-turn conductive ring.

Alternatively, with a constant of the inductance L2 of the secondary coil 18, by varying the inductance L1 of the primary coil 15 as a parameter, constants can be determined in such a manner that formula (3) is satisfied.

Industrial Utilization

As described above, according to the present invention, even in a high frequency band of 20 kHz or higher, the decrease of a driving current (induced current) is very small. Thus, a speaker apparatus of which the decrease of the driving force is very small in a high frequency band of 20 kHz or higher can be accomplished.

In addition, according to the present invention, by optimizing the individual constants of the electromagnetic induction portion, the amount of the induced current can become maximum. Thus, an electromagnetic induction type speaker apparatus with high efficiency can be accomplished.

CLAIMS

1. A speaker apparatus, comprising:

a primary coil disposed in the vicinity of a gap of a magnetic circuit and to which a current corresponding to an input audio signal is supplied;

a secondary coil, disposed in the gap, for inducing a current corresponding to a current that flows in said primary coil; and

a vibrating plate vibrated by said secondary coil with an interaction of the current induced by said secondary coil and a magnetic flux in the gap,

wherein the following formula is satisfied

$$N \times (R1 \times R2)^{1/2} / (2 \pi \times L1 \times (1 - k^2)^{1/2}) \geq 20000$$

where R1 is the DC resistance of said primary coil; L1 is the inductance of said primary coil; N is the number of turns of said primary coil; R2 is the DC resistance of said secondary coil; and k is the coupling coefficient of said primary coil and said secondary coil.

2. The speaker apparatus as set forth in claim 1,

wherein the individual constants R1, L1, N, R2, and k satisfy the following formula at a frequency f in a desired reproduction frequency band

$$2 \pi \times f \times L1^2 \times (N^2 \times R2 + R1) / (N^2 \times X^{1/2}) \geq 0.3$$

$$X = (2 \pi \times f)^2 \times (L1 \times R2 + L1 \times R1 / N2)^2 + \{-R1 \times R2 + (2\pi \times f)^2 \times L12 \times (1 - k2) / n^2\}^2$$

3. A speaker apparatus, comprising:

5 a primary coil disposed in the vicinity of a gap of a magnetic circuit and to which a current corresponding to an input audio signal is supplied;

10 a secondary coil, disposed in the gap, for inducing a current corresponding to a current that flows in said primary coil; and

a vibrating plate vibrated by said secondary coil with an interaction of the current induced by said secondary coil and a magnetic flux in the gap,

wherein the following relation is satisfied

$$15 \quad L1 / L2 = R1 / R2$$

where R1 is the DC resistance of said primary coil; L1 is the inductance of said primary coil; R2 is the DC resistance of said secondary coil; and L2 is the inductance of said secondary coil.

20 4. The speaker apparatus as set forth in claim 3,

25 wherein when the coupling coefficient of said primary coil and said secondary coil is equal to 1, the square of the number of turns of said primary coil is equal to the ratio of the DC resistance R1 of said primary coil and the DC resistance R2 of said secondary coil.

ABSTRACT

In an electromagnetic induction type speaker apparatus, individual constants are set in such a manner that the following formula is satisfied

$$N \times (R1 \times R2)^{1/2} / (2\pi \times L1 \times (1 - k^2)^{1/2}) \geq 20000$$

where R1 is the DC resistance of a primary coil 15; L1 is the inductance of the primary coil 15; N is the number of turns of the primary coil 15; R2 is the DC resistance of the secondary coil 18; L2 is the inductance of the secondary coil 18; and k is the coupling coefficient of the primary coil 15 and the secondary coil 18.

In addition, the constants L1 and L2 are selected in such a manner that the ratio of the inductance L1 and the inductance L2 becomes equal to the ratio of the DC resistance R1 and the DC resistance R2.

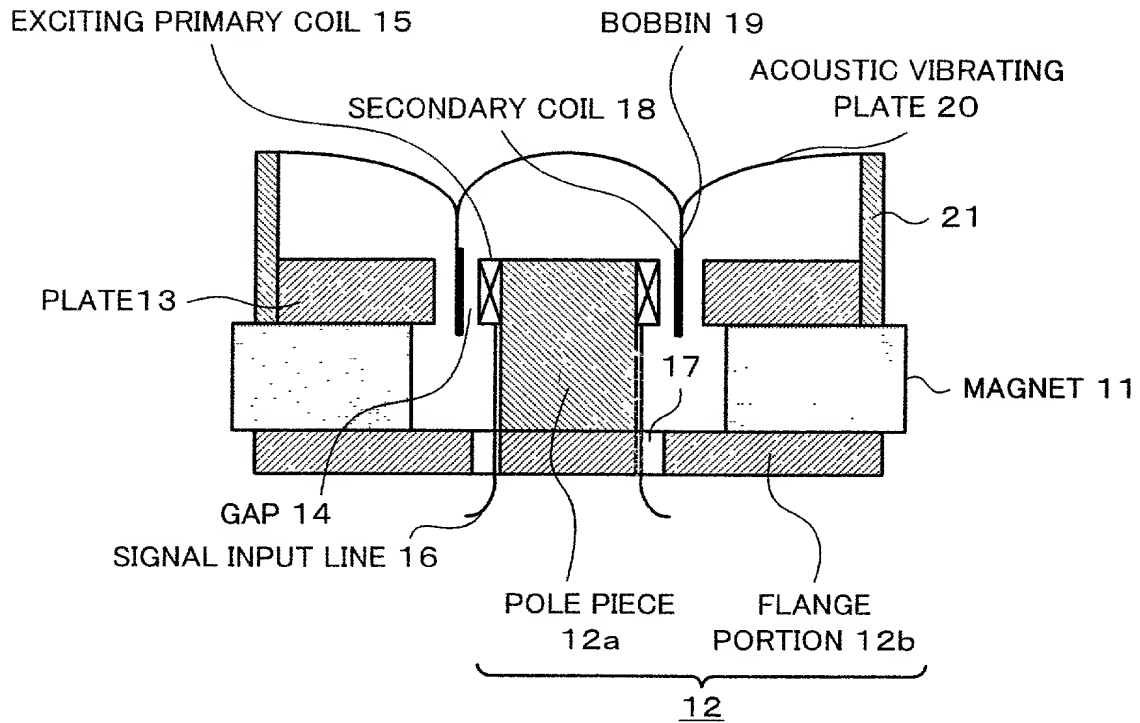
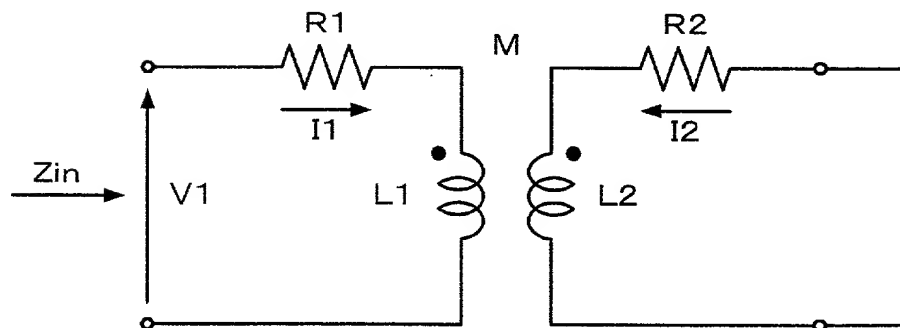
Fig. 1**Fig. 2**

Fig. 3

MEASUREMENT EXAMPLE OF INPUT IMPEDANCE

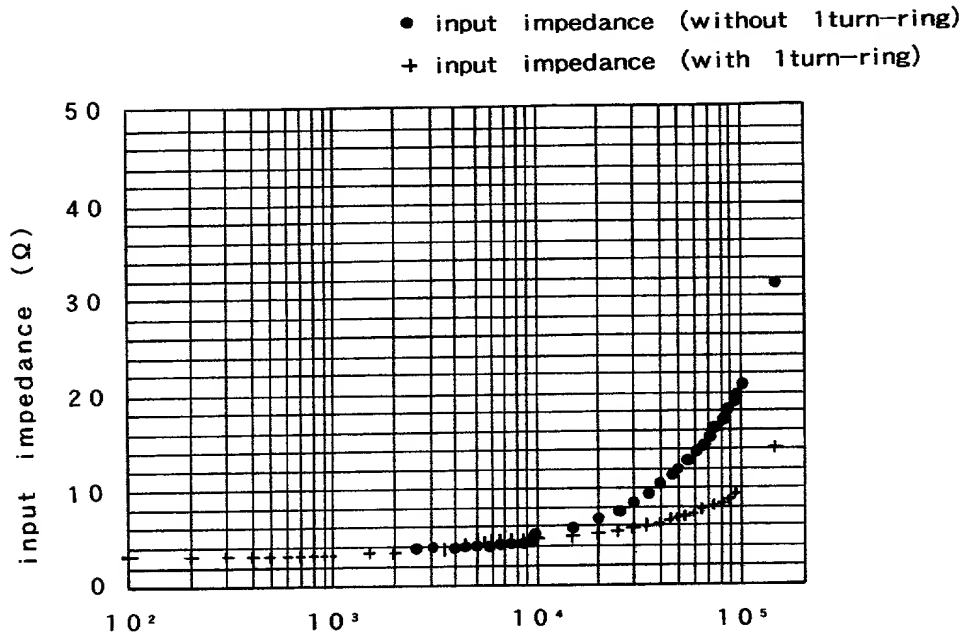
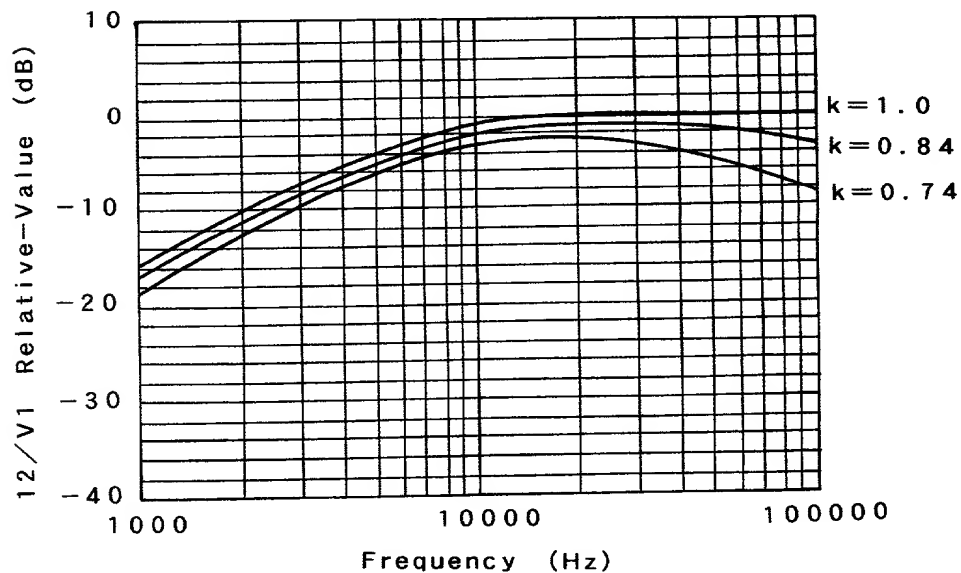
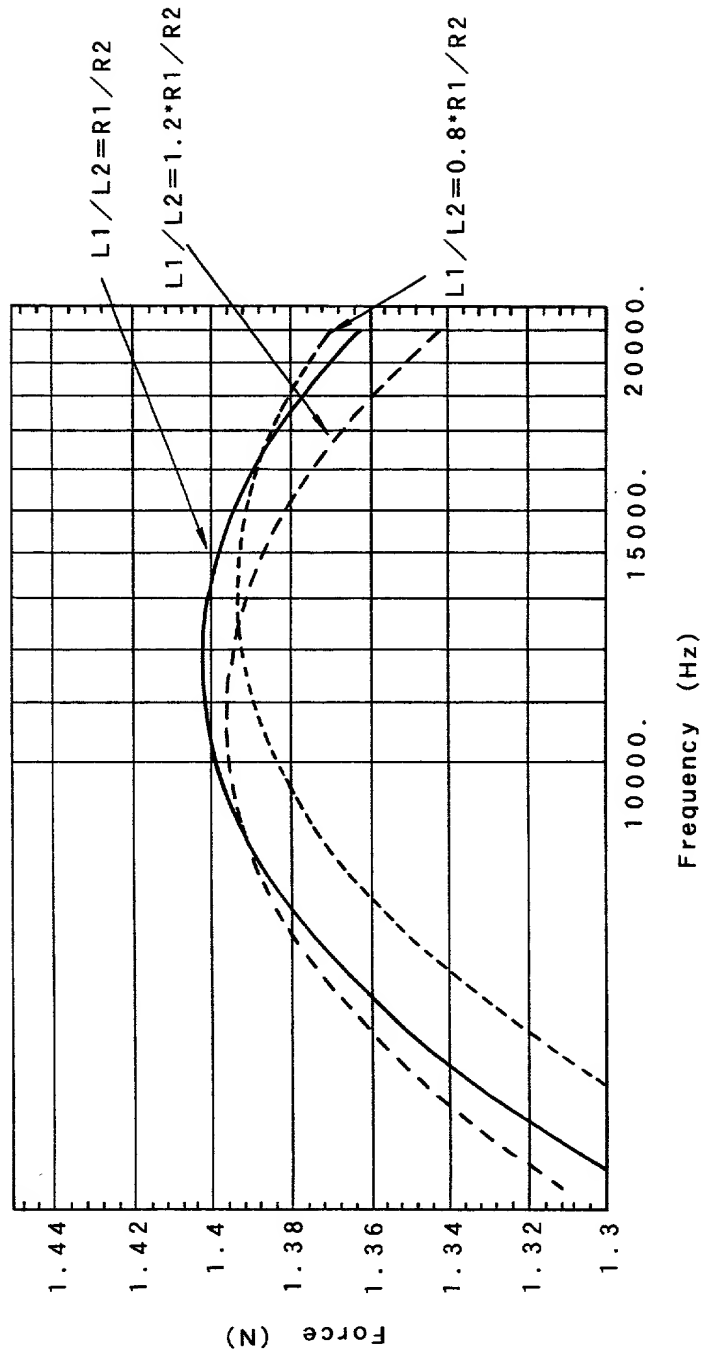
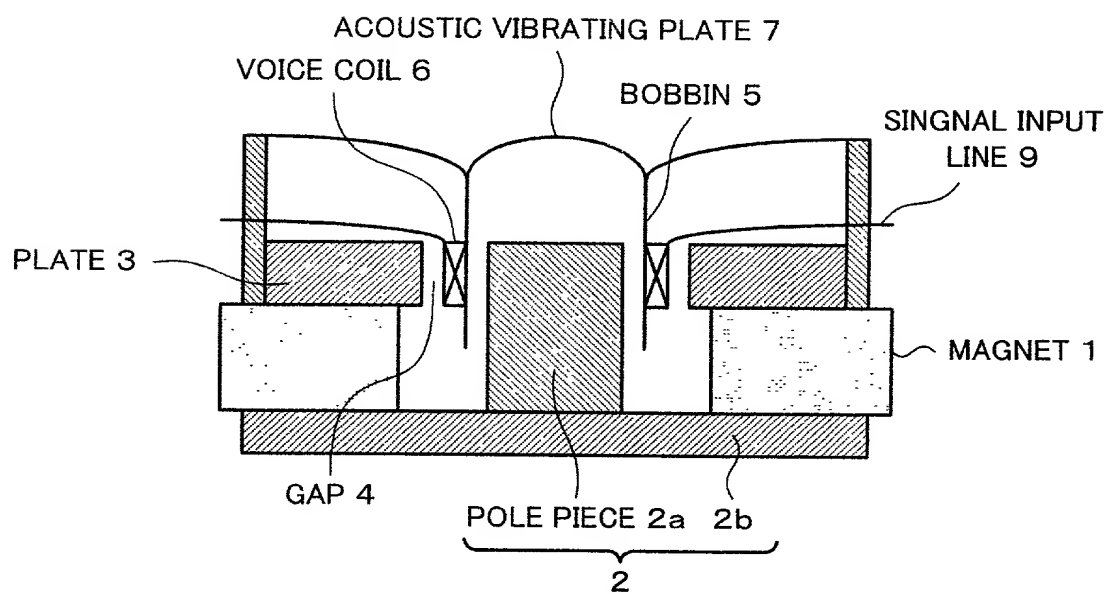
*Fig. 4*CALCULATION EXAMPLE OF FREQUENCY CHARACTERISTIC OF
INPUT VOLTAGE - INDUCED CURRENT

Fig. 5



CALCULATION EXAMPLE OF FREQUENCY CHARACTERISTIC OF
DRIVING FORCE OF ELECTROMAGNETIC INDUCTION SPEAKER

Fig. 6

09/445044

- 11 MAGNET
- 12 THE FIRST YOKE
- 12a POLE PIECE
- 13 PLATE
- 14 GAP
- 15 EXCITING PRIMARY COIL
- 16 LEAD LINE
- 18 SECONDARY COIL
- 19 BOBBIN
- 20 ACOUSTIC VIBRATING PLATE
- 21 SPEAKER FRAME

Attorney Docket _____

DECLARATION AND POWER OF ATTORNEY

As a below-named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **Speaker Apparatus**

the specification of which
(check one)

 X is attached hereto.

 was filed on _____ as

Application Serial No. _____

and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information of which I am aware which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

<u>Number</u>	<u>Country</u>	<u>Filing Date</u>	<u>Yes</u>	<u>No</u>
091565/1998	JAPAN	3/4/98	<u> X </u>	<u> </u>
095809/1998	JAPAN	8/4/98	<u> X </u>	<u> </u>
<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>

Declaration and Power of Attorney

Page 2

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States Application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

<u>Application Serial No.</u>	<u>Filing Date</u>	<u>Status</u>
_____	_____	_____
_____	_____	_____

And I hereby appoint Jay H. Maioli, Reg. No. 27,213; Donald S. Dowden, Reg. No. 20,701; William E. Pelton, Reg. No. 25,702; Peter J. Phillips, Reg. No. 29,691; Gerald W. Griffin, Reg. No. 18,886; Ivan S. Kavrukov, Reg. No. 25,161; Christopher C. Dunham, Reg. No. 22,031; Norman H. Zivin, Reg. No. 25,385; John P. White, Reg. No. 28,678; and Robert D. Katz, Reg. No. 30,141; and each and all of them, all c/o Cooper & Dunham, 1185 Avenue of the Americas, New York, NY 10036 (Tel. (212) 278-0400), my attorneys, each with full power of substitution and revocation, to receive the patent, to transact all business in the Patent and Trademark Office connected therewith and to file any International Applications which are based thereon under the provisions of the Patent Cooperation Treaty.

Please address all communications, and direct all telephone calls, regarding this application to

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Reg. No. 27,213

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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